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AUTHOR Johnson, Virginia M.  
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## ABSTRACT

Researchers have reported that children's writing about mathematical concepts can give teachers valuable insight into students' mathematical understanding. There are, however, factors which place constraints on the adequacy of written products to reveal the quality and degree of children's conceptual understanding. This study examined the relationship between the procedural writing and mathematical writing of third and fourth grade students. Five scripted writing prompts were administered to four classrooms in a suburban elementary school (n=120). Only those responses of children whose parents indicated their approval and who were present for all of the writing samples were considered. Two of these prompts were "domain-free" procedural writing, and three were prompts requesting a response with regard to a mathematical procedure. A significant main effect of general writing ability on the mathematical writing based on the number of words was recorded. The results were examined in terms of the implications for the use of student mathematical writing products as a reflection of mathematical conceptual understanding. Contains 19 references. (Author/PVD)

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Investigating the Relationship Between Procedural  
and Mathematical Writing Responses  
Virginia M. Johnson  
University of California, Riverside

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## Mathematical Writing

### Abstract

Five scripted writing prompts were administered to four classrooms of third and fourth graders in a suburban elementary school. Two of these prompts were "domain-free" procedural writing, and three were prompts requesting an response with regard to a mathematical procedure. A significant main effect of general writing ability on the mathematical writing, based on number of words, was recorded. The results were examined in terms of the implications for the use of student mathematical writing products as a reflection of mathematical conceptual understanding.

## Investigating the Relationship Between Procedural and Mathematical Writing Responses

Recent emphasis on the use of children's writing in the classroom as an assessment instrument has piqued the interest of both educators and researchers. In 1989, the National Council of Teachers of Mathematics recommended in their Curriculum and Evaluation Standards for School Mathematics that meaningful communication, such as talking, listening, reading and writing, be emphasized in mathematics classrooms. Researchers have reported that children's writing about mathematical concepts can give teachers valuable insights into students' mathematical understanding (Wadlington, Bitner, Partridge, & Austin, 1992).

It is commonly accepted by educators and researchers that one of the purposes of assessment is to inform students, parents, and interested others about student progress. The call for "authentic" assessment has increased focus on the use of student products such as those collected in portfolios, which

include children's written communication. The use of children's written products in assessment is based on the assumption that such writing can serve as an indicator of conceptual understanding.

However, there are factors which place constraints on the adequacy of written products to reveal the quality and degree of children's conceptual understanding. There is some consensus about the difficulty that is experienced in putting mathematical concepts into verbal form. In addition, once verbalization is possible, the differences in the nature and quality of spoken verbalizations and written communication yield further constraining factors (Gumperz, Kaltman, & O'Connor, 1984; Peyton, 1988; Shuy, 1988). Another consideration is the variation in the character of children's writing due to differences in levels of cognitive development, and its impact on the expression of mathematical understanding (Bereiter & Scardamalia, 1987; Berninger, 1992; Gelman & Byrnes, 1991). An additional factor for consideration is the extent to which the child's general ability to write impacts the nature and quality of his/her mathematical writing. Little has been written about the elements which may place limitations on beginning writers, in terms of the adequacy of

children's written communication to reflect conceptual mathematical understanding. In light of these concerns, this analysis will add to the body of knowledge in regard to these possible constraining factors through the examination of the connection between general writing ability and written mathematical expressions of children by comparing children's responses to both general and mathematical writing prompts.

#### Theoretical Foundation

The writing process begins long before children's attempts to create a product of written speech. Its genesis lies in the child's acquisition of language.

Children acquire language proficiency during the early years of life. Even before the awareness of language is developed, children have experienced it in numerous ways in their environment, in the form of gestures, nonverbal communication, interactions with mother, and so on.

Developmental psychologists and others, including Piaget and Vygotsky, proposed that children acquire language in stages which begin with the simple and move

gradually toward complex patterns of speech as the child matures. The general ability, or inability, to express thoughts and concepts in words, is related to the child's overall language proficiency. It can be concluded that children must have at least a fundamental understanding of a concept before they can generate language for it (Gleason, 1985).

Although writing is considered to be a difficult task, it is a natural consequence of language development (Bereiter & Scardamalia, 1987), where children move through developmental stages. According to Alexander Luria, a student of Vygotsky, the ability to write can be divided into four overlapping stages, which are not solely determined by the age of the learner: 1) Undifferentiated; 2) Differentiated; 3) Pictographic; and 4) Ideographic (Klein, 1985).

Because an understanding of the developmental progression of the writing process is vital to this discussion, a clarification of Luria's stages is presented herein.

The Undifferentiated Stage refers to the child between the ages of 3 and 5 years of age. This can also be called the "pre-writing" or "pre-instrumental" stage, as the role of writing is neither functional nor instrumental. During this period of time, a child's

notations offer no assistance in remembering. In addition, if "notes" are written, most children do not refer to the paper when asked to remember. There is some indication that children can remember information better without writing. In fact, attempts to write "notes" may interfere with remembering (Klein, 1985).

In the second, or Differentiated Stage (from 4 to 6 years), the child is in the process of connecting the meter and amount of verbal expression with the symbols of writing, and discovering that language is a tool through which information and facts can be symbolized and abstracted (Luria, 1976).

In studies conducted with young children, Luria reports that children use numbers, in the form of scrawls or marks, to help recall information which has numerical descriptors (i.e. two balls, four cookies, etc.) In addition, the children were found to alter the intensity of their written forms to indicate a color modifier of key nouns (ie red dress, white cat, etc.) (Klein, 1985). At this point, the written form serves a mediating purpose and facilitates recall. That is, the child has intentionally used the written expression to assist the remembering of information. Children gradually make sense out of random marks, and move into using figures and pictures (Luria, 1982).

This stage is called the Pictographic Stage and includes children from ages 4 through 6). It is during this phase that pictures are drawn to convey a verbal meaning. Drawing begins in children when spoken expression has become automatic ( Buhler, cited in Bereiter & Scardamalia, 1987). According to Sully, children's initial drawings are produced from memory, with no attempt at representation. Instead, drawing is "graphic speech" which emerges from the foundation of verbal ability (Cited in Cole, et al, 1978). Young, et al, indicate that a child's representations in memory are not simple, but are simplified through the agency of their speech (1970).

The final stage is the Ideographic Stage, where children understand and utilize symbolic language. During this stage, the link of speech gradually diminishes and language begins to directly represent the things which it describes (Klein, 1985).

Although the Ideographic Stage is Luria's final stage, it marks the beginning of the child's written text production. It is not unexpected that individual differences would emerge also at this point, including the level of cognitive development and language ability. There are two additional factors which impact children's production of written text that will be

examined here: cognitive load and the mechanical demands of writing.

The interface between mental processes of language production and the physical process of transcription takes place in short-term memory. After language is composed, it is held in short term memory store until it is translated into verbal language. The rules of language are applied and language production is edited. In his "Monitor Model", Krashen asserts that language is produced that is compatible with the rule system that has been acquired during the child's language development (Bereiter, Fine, & Gartshore, 1987). Since these writing protocols must be applied intentionally by beginning writers, some of their short term memory store is utilized for this purpose, thus restricting their ability to generate text.

Another factor which restrains children's writing production is the interference of the requirements of the very act of writing, such as sentence formation, making sense, and keeping in mind the intended audience (Seigler, 1991). If the child must attend to low-level writing functions such as spelling and punctuation, there is less attention available for focusing on composition and text generation. In studies conducted by Bereiter & Scardamalia (1987), it was observed that

removing concerns about the mechanics of writing resulted in greater quantity of text production. This is meaningful because earlier findings of Scardamalia and Bereiter (1978, 1979) concluded that "the number of words correlate substantially with indicators of quality or maturity applied to writing."

On this foundation, this study examined the relationship between procedural writing and mathematical writing of third and fourth grade students. Given Scardamalia and Bereiter's conclusion that the number of words written correlates highly with writing quality, the first-level analysis of a portion of the data compares the number of words written in response to procedural and mathematical prompts. It is to be noted that this analysis does not include the quality of this writing, such as syntactical difficulty, semantic usage, or completeness of expression of concepts. These will be studied in future examinations of the data. Analyses underway include oral versus written expression of mathematical concepts as reflections of mathematical understanding, the possible connection of gender differences in mathematical writing, and the relationship between the number of words written and the completeness of the child's expression of mathematical concepts.

## Method

### Subjects

The availability sample consisted of 120 third and fourth grade students in four classrooms in Southern California schools. All children in these classes participated in the writing protocol, but only the responses of children whose parents indicated their approval and who were present for all of the writing samples were considered.

### Design

This analysis included the examination of two variables. The predictor variable was procedural writing, which was measured in number of words recorded from a written responses to a "domain-free" writing prompt, that is, a request for writing about something that is not presumed to rely on domain-specific knowledge. To control for time factors, two procedural writing responses were collected, one on the first day, and the other on the last day of data collection. The means of these two scores were computed and used as a single procedural writing score.

The criterion variable represented scores on

mathematical writing samples, which was measured in number of words written in response to a mathematical writing prompt. Using the number of words as a basis for comparison and evaluation is based on the suggested findings of Berninger et al (1992) that "both the number of words and clauses correlated significantly with mean ratings of quality", and Bereiter & Scardamalia (1978, 1979) "the number of words correlate substantially with indicators of quality or maturity applied to writing."

These writing samples were grouped into three groups, high (101-175), medium (51-100), and low (0-50). Because the cell n's were small in the high group, the high and medium groups were combined. These data were compared using a two-way Fixed effects ANOVA, with one between-group factor and unbalanced cells.

### Procedure

This study was implemented through a five-part experiment protocol in four classrooms of third and fourth graders. Five scripted writing prompts were given to the entire classes, on consecutive days, by the classroom teachers. On the basis of McCutchen's (1986) assertion that children write more fluently when discussing things about which they are knowledgeable,

two baseline, "domain-free" procedural writing prompts were given where the children wrote about something they could do very well (Prompt 1) and how to play a favorite game or sport (Prompt 5).

The three mathematical prompts (Prompts 2, 3, and 4) were focused on a particular mathematical concept that had recently been studied in the classrooms. These writing samples represented three levels of thinking about mathematical concepts: 1)procedural sequence for solving the problem-type (Prompt 2); 2) generation and explanation of important ideas relevant to the concept (Prompt 3); and 3) generation of problems using the concept in a situation of application (Prompt 4). Only two of the mathematical writing samples, prompts 2 and 3, were considered in the analysis because of inconsistency of prompt execution by the classroom teachers.

## Results and Discussion

### Quantitative Analysis

The results, combining the medium and high group, are shown on Table 1. These data indicate that the probability that these results are due to chance factors is very low ( $p = 0.0011$ ). This leads to the

rejection of the null hypothesis with respect to procedural writing, since  $p < 0.05$ , indicating significant main effects.

These preliminary results indicated that there is a correlation between students' ability to write on the domain-free prompts and on the mathematical prompts, and that there is a very low probability that this correlation is due to chance factors. In other words, this suggests that the student's general writing ability, or lack thereof, impacts written articulation of mathematical processes. An additional plausible explanation for the observed phenomenon is that those children who are weak in writing skills may also be weak in mathematical understanding. Given this focus, it could be suggested that caution be used in inferring the adequacy of children's written expressions as the primary basis for assessing mathematical understanding.

Further work is needed to more clearly determine the constraints on the assessment value of children's mathematical writing.

In addition, further examination of the data indicated a significant correlation ( $r=0.5313$ ,  $p=.0192$ ) between the number of words written on the writing prompts and the rubric score reflecting the quality of the writing. This supports the conclusions of other

researchers, i.e. Scardamalia & Bereiter and Berninger.

### Qualitative Analysis

A qualitative examination of the data included the use of a rubric to analyze the writing prompts with regard to the quality of the writing. This same rubric was then applied to a transcript of the oral responses of the children's videotaped interviews.

In every instance , the rubric score of the oral expression of mathematical understanding surpassed the written expression. This difference ranged from 1 to 5 points on a 10-point scale. This suggests that children are better able to express themselves orally than in writing. This may be due to the mechanical writing constraints, or perhaps the difficulty which children experience when attempting to put mathematical concepts into words.

A surprising finding in this analysis was that although the quality of verbal expression was superior in the oral presentations of mathematical understanding, the number of words spoken was lower than the number written. The mean number of words written was 64.46, while the spoken responses had a mean of 23.92.

In the examination of the transcripts and

then waited for a response from the examiner. Perhaps they were soliciting feedback, as is standard in face-to-face conversations. Most of the students orally answered the examiners questions by providing one step or point, and then waited for further questions or directions.

On the other hand, this occurrence could be the result of less thinking time for organizing a response. Regardless of the origin of this phenomenon, it appears that this effect was strong enough to compensate for the anticipated possibility of constraints on writing that may be due to the lack of audience input and context.

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Appendix

Table 1

ANOVA Summary Table for Study Investigating the  
Relationship between Procedural Writing and  
Mathematical Writing

| Source             | df | <u>SS</u> | <u>MS</u> | <u>F</u> | <u>p</u> |
|--------------------|----|-----------|-----------|----------|----------|
| Procedural Writing | 1  | 2.36      | 2.36      | 12.14    | 0.0011   |
| Error              | 44 | 8.80      | 0.63      |          |          |
| Corrected Total    | 45 | 10.96     |           |          |          |